Robotic Isotopic Identification Device (IID)

Deactivation and Decommissioning Focus Area

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INNOVATIVE TECHNOLOGY

Summary Report

Robotic Isotopic Identification Device (IID)

OST/TMS ID 3063

Deactivation and Decommissioning Focus Area

Demonstrated at
Idaho National Engineering and Environmental Laboratory
Idaho Falls, Idaho

INNOVATIVE TECHNOLOGY
Summary Report

Purpose of this document

Innovative Technology Summary Reports are designed to provide potential users with the information they need to quickly determine whether a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend that a technology be considered by prospective users.

Each report describes a technology, system, or process that has been developed and tested with funding from DOE's Office of Science and Technology (OST). A report presents the full range of problems that a technology, system, or process will address and its advantages to the DOE cleanup in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. Innovative Technology Summary Reports are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

All published Innovative Technology Summary Reports are available on the OST Web site at http://apps.apps.em.doe.gov/ost/itsrall.html.

CONTENTS

APPENDICES

SECTION 1
SUMMARY

Background

The United States Department of Energy (DOE) continually seeks safer and more cost-effective technologies for use in decontaminating and decommissioning nuclear facilities. To this end, the Deactivation and Decommissioning Focus Area of DOE's Office of Science and Technology (OST) sponsors “Large-Scale Demonstration and Deployment Projects” to test new technologies. As part of these projects, developers and vendors showcase new products designed to decrease health and safety risks to personnel and the environment, increase productivity, and lower costs.

The Large-Scale Demonstration and Deployment Project (LSDDP) at the Idaho National Engineering and Environmental Laboratory (INEEL) has generated a list of statements defining specific needs or problems where improved technology could be incorporated into ongoing decontamination and decommissioning (D&D) tasks. One of the stated needs was for developing technologies that would reduce costs and shorten D&D schedules by providing radiological characterizations of rooms, buildings, or facilities. Engineers at the INEEL identified the Russian Gamma Locator Device (GLD) as being one such technology that could provide economic and safety benefits to the INEEL D&D program. The GLD and it’s benefits are discussed in the Innovative Technology Summary Report OST/TMS ID 2991, while the IID is discussed in this report.

The LSDDP demonstration as originally envisioned was to use the GLD to collect video and gamma radiation levels in the Liquid Waste Treatment Facility at Test Area North (TAN)-616. The capabilities of the GLD were demonstrated to INEEL LSDDP personnel at the Russian Research and Development Institute of Construction Technology (NIKIMT) February 27-March 3, 2000. During the visit it was learned that another technology provider had designed and built a technology that could remotely identify the isotopes that were the source of the radioactivity. This technology also operated non-tethered and could possibly be used in conjunction with the GLD. The addition of this Isotopic Identification Device (IID) would increases the benefit to the DOE by reducing the number of entries required and unnecessary personnel exposure in radioactively contaminated areas. The decision was made to integrate the technologies and demonstrate the GLD with the IID.

The demonstration activities were separated into two phases. During Phase I, in Russia, the IID and the GLD were combined into a common housing with a common power supply, common communications, and common signal transmitters and receivers. During phase II the combined Russian GLD/IID was shipped to the U.S. where it was mounted on the INEEL robot and demonstrated in the TAN-616 facility.

A Russian delegation from NIKIMT visited the INEEL March 17-24, 2001 to view the facility and the robot`. It was established that the INEEL robot, “ATRV-Jr” (a tetherless robotic vehicle), would be the platform used to move the GLD and IID within the facility.

When the IID technology first arrived at the INEEL it was shipped to CFA where it was surveyed by RCTs to ensure no contamination was present. After it was surveyed, the equipment was transported to the Idaho Falls, North Boulevard Annex (NBA) for unpacking and integration onto the INEEL robotic platform. The IID was then set up and calibrated using low-level radioactive sources. After the initial setup and functional testing was complete, a demonstration was provided to the media and interested dignitaries on the operation and potential use for this type of innovative technology.

Benefits and advantages specific to the IID technology include cost reduction for first-time personnel entry into a radiologically contaminated D&D facility, accelerated schedules, in situ real-time isotopic identification, reduction in personnel radiation exposure and a more detailed and complete radiological survey.

Baseline Technology

Historically at the INEEL, radiological control and industrial safety personnel first enter a facility in order to establish accurate environmental conditions for planning purposes. When performing an initial radiation survey, the radiological control technician (RCT) uses a standard Geiger-Mueller pancake probe to gather radiological information. However, this information does not include isotopic identification information and therefore is not always adequate for all characterization activities. Once this initial entry has been completed, a video technician may also be required to enter and collect video footage. This was the case at TAN-616. A video technician was sent in to obtain footage of the facility for future work planning purposes. Finally, a team of sampling technicians (see Figure 1) was sent into the facility to collect samples for determining the accurate levels of contamination and to identify which isotopes were present in the facility for planning decontamination and disposal work.

Figure 1. Baseline technology collecting samples for laboratory analysis.

Innovative Technology

This technology and the demonstration were made available through the auspices of the DOE-HQ International Programs and the DOE-NETL (National Energy Technology Laboratory) D&D Focus Area. A robot was provided and operated by the INEEL robotics crosscut program to mobilize the GLD and the IID to remotely characterize the rooms in TAN-616.

The GLD provides three-dimensional characterization data of radioactivity in areas of extremely high activity. The GLD scanned several rooms and quantified the level of radioactivity while cameras aboard the GLD simultaneously videotaped those areas being scanned. The radioactivity levels were overlaid on the video and displayed at a remote PC monitor located outside the contaminated area. This technology is unique to competing U.S. technologies because it operates on radio frequencies completely autonomously, allowing it to maneuver around corners and transmit through congested areas where cables or tethers would entangle and possibly become damaged. It has a broader range of sensitivity (i.e., 60KeV to 6MeV compared with 100KeV to 2MeV); and it has a broader scanning angle (i.e., 330 degrees horizontal and 125 degrees vertical compared with 73 degrees horizontal and 55 degrees vertical). The distance from the GLD/IID to the hot spot is measured by a laser distance meter and can range from 0.5 to 100 meters. Exposure time ranges from 5 to 60 seconds. Different levels of radioactivity are color-coded to enable the viewer to pinpoint the hot spots.

The IID can identify the isotopes generating the radioactivity being characterized by the GLD. The IID was programmed to identify Cs-137, Co-60, and Am-241, but it can be programmed to identify other isotopes as well. To identify isotopes the IID uses computer software to identify energy peaks and compare those peaks to enegy levels of specific isotopes.

Figure 2. Combined Russian IID and GLD Scan Head.

The IID is a characterization device designed and built in Russia by specialists in physics, mechanics, electronics, computer programming, television, and radio transmission. It is a remote-controlled system, comprised of a detector, analyzer and control system.

- Detector components

    - Collimator equipped with a spectroscopic sensor and the electronic units for preliminary processing of incoming signals
    - Scanning electro-mechanical devices
    - Electromechanical unit for remote screening of the collimator
    - Laser distance meter
    - Isotopic dosimeter unit
    - Radio high-frequency receiving/transmitting device
    - Onboard computer
    - Batteries.

- Control System
    - Computer and printer
    - High-frequency receiver/transmitter device
    - TV signal receiver
    - Software for data processing
    - Power supply sources.

Demonstration

The IID was demonstrated in July of 2001 at TAN-616. TAN is located at the north end of the INEEL, about 27 miles northeast of the INEEL's Central Facilities Area (CFA). TAN was established in the 1950s by the U.S. Air Force and Atomic Energy Commission Aircraft Nuclear Propulsion Program to support research in nuclear-powered aircraft. Upon termination of this research, the area's facilities were converted to support a variety of other DOE research projects. TAN-616 was built in 1954 as a liquid waste treatment facility. There are various levels of contamination present in the facility as a result of treating thousands of gallons of liquid nuclear processing waste.

Figure 3. TAN- 616.

The IID was compared with the following baseline activities: the initial RCT entry, the entry to collect video footage, and a final entry to collect sample information. The IID was able to collect video footage, and isotopes present in a single unmanned entry.

Three rooms within TAN-616 were surveyed using the IID: the Operating Pump Room, the Control Room, and the Pump Room. Figure 4 shows the Pump Room. All of the rooms are filled with process piping and equipment at various levels, making a manual survey difficult and time consuming.

Figure 4. TAN-616 Pump Room showing congested area where data needed to be taken.

Contacts

Technical

Technical Information on the Robotic IID
Dr. Nikolai Sidorkin, director of Robotics, NIKIMT, (7-812) 489-90-95.

Technology Demonstration
Frank Webber, D&D manager, INEEL, (208) 526-8507, flw@inel.gov.

Donna Nicklaus, facility D&D Project manager, (208) 526-5683, nickdm@inel.gov.

Craig Conner, test engineer, INEEL, (208) 526-3090, craig@inel.gov.

Management
Steve Bossart, project manager, DOE National Energy Technology Laboratory, (304) 285-4643, steven.bossart@netl.doe.gov.

Willettia Amos, DOE Idaho Operations Office, (208) 526-4097, amoswd@inel.gov.

Dick Meservey, project manager, INEEL Large-Scale Demonstration and Deployment Project, (208) 526-1834, rhm@inel.gov.

Licensing
Because the IID transmits data via radio frequency (RF), it is necessary to obtain licensing for the frequency used. The IID currently operates at 3.4 GHz and 780 MHz for video and data transmission. The power level of the RF signals is .015 W and 1.1 W, respectively.

Permitting
No other permitting activities were required.

Other
All published Innovative Technology Summary Reports are available on the OST Web site at http://apps.apps.em.doe.gov/ost/itsrall.html. The Technology Management System (TMS), also available through the OST Web site, provides information about OST programs, technologies, and needs. The OST/TMS ID for IID is 3063.

SECTION 2
TECHNOLOGY DESCRIPTION

Overall Process Definition

Demonstration Goals and Objectives

The overall purpose of this demonstration was to assess the benefits that may be derived from using the IID to collect initial video and radiation surveys in a contaminated facility. The IID was compared with the baseline technology, which involved an initial entry into the facility by RCTs to determine contamination levels and radiological content in order to establish safe working limitations for D&D activities. A second entry was made by a video team to collect footage for planning purposes and a final entry to sample various locations in the facility to determine contamination levels and isotopes present.

During the TAN-616 demonstration, the Operating Pump Room was the first room to be characterized. During the initial entry of baseline characterization, the RCT collected sixteen smears and recorded ten dose measurements at various locations in the room. This preliminary information was required to allow the sample technicians into the area to collect samples for the baseline comparison data.

The primary goal of the demonstration was to collect valid characterization data to make a legitimate comparison between the IID technology and the baseline activities in the areas of:

- Cost
- Productivity
- Ease of use
- Limitations and benefits
- Data quality
- Reducing radiation exposure to workers

System Operation

The IID operates completely autonomous, using on-board 12-V DC batteries for power (see Figure 5). All signals are transmitted via two radio frequencies, 780 MHz for data transmission and 3.4 GHz for video data. The maximum duration or length of operation for the IID varies based on the size of the battery and the number of movements or positions required for each scan. For the demonstrations at the INEEL, 4 hours was the longest time the IID operated between battery charges. This was the longest time required to complete the scans in each area identified for the demonstration. If a larger area or more detail of an area is required, it is recommended that a larger battery be used.

The robot has an independent 12-VDC battery and a 3-6 hour run time depending on the terrain and number of movements. The robot has onboard cooling fans that were disabled to prevent radioactive contaminants from entering the internals of the robot. Tests were made prior to using the robot for this application to ensure the electronic components would not over-heat due to reduced air flow. The entire system was covered with plastic material to prevent external radioactive contamination from coming in contact with the robot.

Integration of the GLD/IID onto the robot required fabrication of a base plate that bolted onto the robot and mated to the existing four-bolt pattern on the GLD/IID base. The only wiring requirements were the 12-V power leads that ran from the GLD/IID base to the battery mounted on top of the robot. This battery was specifically purchased for the GLD/IID operation and did not power any part of the robot.

Technical specifications/characteristics of the Isotopic Identification Device are as follows:

Spectrometric Block of Detection – SBD detector consists of:

- scintillating monocrystal Cs J(Tl) with dimension 12×12×12 mm;
- photodiode which has an optical contact with scintillator;
- impulse shaper;
- power supply filter.

Figure 5. Computer controls, GLD/IID scan head, and antennas.

SECTION 3
PERFORMANCE

Demonstration Plan

Problem Addressed

Both DOE and the U.S. Commercial Utility Sites have a high level of interest in this new technology and its ability to effectively and remotely characterize radioactivity. For this demonstration, a previously characterized radiological facility was evaluated as part of the ongoing D&D activity at TAN-616. Several areas were identified and scanned so that an adequate comparison between the innovative technology and baseline could be made.

The scope of this project was to demonstrate the IID technology for identification of isotopes at TAN-616. Technical data was collected for the productivity, ease of use, limitations and benefits, radiation exposure reduction to workers and the potential for cost and schedule savings compared with the baseline technology utilized by the INEEL.

Demonstration Site Description

The INEEL site occupies 569,135 acres (approximately 890 square miles) in Southeast Idaho. The site consists of several primary facility areas situated on an expanse of otherwise undeveloped, high-desert ecosystem. Structures at the INEEL are clustered within the primary facility areas, which are typically less than a few square miles in size and separated from each other by miles of undeveloped terrain.

TAN is located at the north end of the INEEL, about 27 miles northeast of the INEEL's CFA. TAN was established in the 1950s by the U.S. Air Force and Atomic Energy Commission Aircraft Nuclear Propulsion Program to support research in nuclear-powered aircraft. Upon termination of this research, the area's facilities were converted to support a variety of other DOE research projects.

TAN-616 was built in 1954 as a liquid waste treatment facility. As a result of treating thousands of gallons of liquid nuclear processing waste, there are various levels of contamination present in the facility, ranging from one or two milli-rem per hour to several hundred milli-rem per hour.

Major Objectives of the Demonstration

The major objectives of this demonstration were to evaluate the IID against the baseline sampling in the following major areas:

- Cost
- Productivity
- Ease of use
- Data quality
- Limitations and benefits
- Reduction in radiation exposure to workers

Major Elements of the Demonstration

NIKIMT personnel operated all controls and were responsible for the IID during the demonstration. INEEL robotics personnel operated and were responsible for the robot and integration of the equipment on the robot. NIKIMT personnel were also responsible for making the IID compatible with the INEEL robot prior to shipment to the INEEL. During the demonstration, the following areas were evaluated:

- Identification of the radio frequency
  - Any interference generated
  - (Meets approval of the National Telecommunications Information Administration for use at the INEEL)
  - Operable distance
  - Power requirement to operate the signal
  - Data emissions
  - Integration to the INEEL robot
  - Isotopic enhancement
- Mobility (Pan and Tilt)
  - Pan (320-degree rotation, +), Tilt (20 degree down and 90 degrees up)
  - Speed and control capabilities
  - Technical requirements for integration to INEEL robotic device

- Radiological sensitivities
  - Low limit (30 to 500 KeV).
  - Mid range (500 KeV to 1.5 MeV)
  - High range (1.5 MeV to 3 MeV)
  - No activity
- Decontamination process
  - Easy to decontaminate
  - Process involved
  - Recovery mechanism
- Identification of the data format
  - Type of computer software
  - Format of the data result
  - Size of files generated
  - Time required to post-process and screen the data
- Replacement cost to the INEEL if contaminated and not recovered from contaminated area or damaged beyond repair.

The IID demonstration started in July 2001 at TAN-616. This building was scheduled for D&D beginning in the fall of 2001. For the baseline technology, three rooms were selected for collecting samples. These rooms were the Control Room, the Operating Pump Room, and the Pump Room. The baseline characterization activities for TAN-616 started during the summer of 2000 and continued through the fall of 2000.

During the baseline characterization, RCT's collected samples at various locations in the facility. Workers collected samples from paint, debris, sludge, and concrete. In addition to the samples, they collected video images in each room to provide insight for D&D planners when they prepare to decommission the facility.

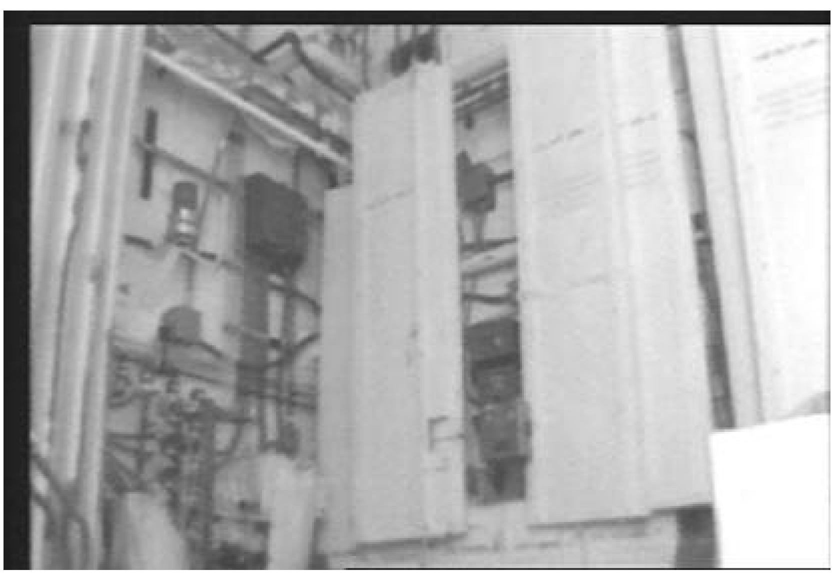


Figure 6. IID collecting isotopic measurements on a wall.

Figure 7. IID operating remotely with the INEEL robot.

Results

Test engineers maintained detailed field notes in a logbook on all activities associated with the demonstration process. They also recorded all pertinent information regarding field implementation and execution during the verification tests, including the time required to set up and relocate the equipment during each portion of the testing. Information was collected on the number of scans performed on each object and environmental conditions prior to, during, and following the demonstration of the IID. Specific data were collected for the IID during the demonstration to demonstrate the effectiveness of the IID while operating in conjunction with the GLD. This allowed an independent evaluation of the IID separate from the GLD. These field notes and other data were collected in hardbound logbooks. In addition, INEEL test engineers reviewed all data generated during the test stages of the IID.

Each of the scans is composed of several point measurements that range from 9 to 25 points. A single scan could cover several square feet on a wall or network of piping, or may be a very detailed scan of a smaller area such as 1 square foot of wall space. In order to collect similar data using the baseline technology, separate samples or smears would have to be collected and sent to a laboratory for analysis. The IID takes under 2 minutes to perform a typical 9 point scan to identify which isotopes are present at a specific location.

Physical samples for all the 2000/2001 characterization activities were collected in accordance with the report; Field Sampling for Characterization for the RCRA Closure and Decontamination and Decommissioning of TAN-616. The radiological analysis confirmed the presence of alpha, beta, and gamma-emitting radionuclides. The most prevalent alpha-emitting radionuclide found was americium Am-241; (see Table 2). The most prevalent gamma-emitting radionuclides were cobalt Co-60 and cesium Cs-137.

Operating Pump Room Results

During the IID demonstration, 11 scans were made. The location of these scans is shown in Figure 9 by the bold numbers (1-11). Each of the 11 scans were composed of several point measurements that ranged from 9 to 25 points. Figure 8 shows a 9-point scan taken in the Operating Pump Room. A total of 120 point measurements were made using the GLD/IID in the Operating Pump Room. Some of the points were on the walls, some on control valves, and one on the floor. In order to collect similar data using baseline measurements, nine separate samples or smears would have been collected, whereas using the IID, all nine measurements were made in under two minutes. The IID uses a laser to measure distance to each point. Therefore, each measurement has been corrected for distance away from the detector.

The Operating Pump Room was the first room to be characterized during the demonstration of the IID at TAN-616. The RCTs collected five smears (A,B,E-G) at various locations in the room during the initial baseline entry (Figure 9). These baseline sample locations are identified by bold capital letters shown in Figure 9. During the sampling phase of baseline characterization three additional smears were collected and four samples were collected (sludge, paint, and other materials). These seven samples were sent to a laboratory for isotopic analysis. The cost for each sample was $330/sample.

During these scans, each of the measurements taken during baseline characterization was validated using the IID. Cobalt-60 and Cesium-137 was identified in these locations. In addition, elevated radiation readings were found on the north wall in three locations. Elevated radiation readings were also found between the hold tank and sink on the west wall and on a pipe above the sink. These elevated readings were not reported during the baseline characterization.

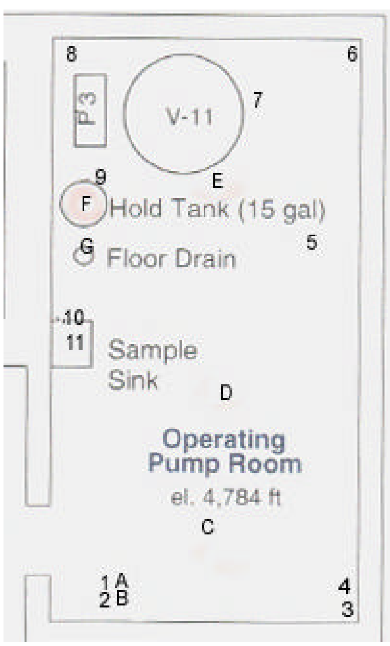


Figure 9. Characterization of the Operating Pump Room

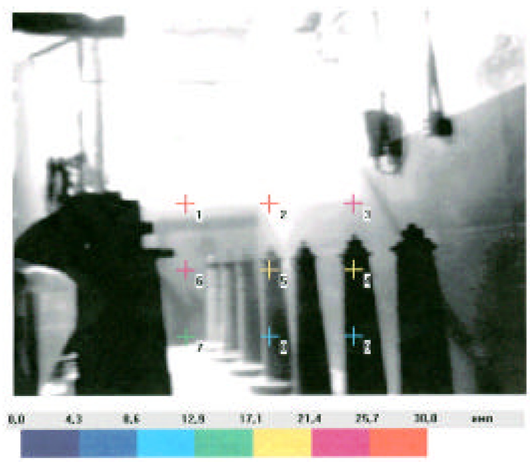


Figure 8. Radiation Scan using Robotic IID in the Operating Pump Room

Note: Each cross hair represents a separate scanning point. The color of the cross hair indicates the radiation level that correlates to the scale below the graph. The units are in total counts in a given 10- second scan time.

Control Room Results

During the initial entry, RCTs collected two smears in the Control Room. The results of the smears were readings less than 0.5 mR/hr. Two paint samples were sent to the laboratory for analysis, but neither had detectable radiation or identified isotopic content. One scan was performed in the Control Room using the IID. Figure 10 shows the location of the baseline samples represented by bold letters (A-B) and the location of the IID scan by the bold number 1.

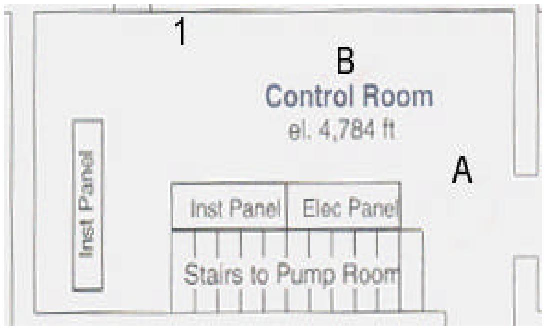


Figure 10. Characterization of the Control Room.

The IID scanned a pipe on the north wall of the Control Room and found significant levels (greater than 4,000 counts per minute above background) of gamma radiation. This scan was analyzed to determine what isotopes were present. Both cobolt and cesium were identified in these locations. No other measurements were made in the Control Room.

Pump Room Results

RCTs collected seven smears (A-B, D-H) during the initial entry in the Pump Room and reported one direct measurement (C) (see Figure 11). Radiation levels in the pump room were much higher than those observed in the previous two rooms. Sample technicians also collected eight smears and collected a sludge sample and a sample of rubber hose. These samples were sent to a laboratory for analysis. Results of the smears indicated primarily cobalt and cesium were present in this area. Sample locations for baseline measurements are shown in Figure 11 as represented by the bold letters.

The IID performed eight scans (1-8) in the area. These eight scan locations are shown in Figure 11 as denoted by the bold numbers. The number of point measurements per scan ranged from 1 to 20 points, with a total of 91 point scans taken in the entire room. In this room, the IID and robot began to lose communication when they began passing the first pump (P-1) heading in the north or upward direction on the map, which was approximately half of the way across the room going in the north direction. The loss of communication with the robot and IID resulted from a combination of; the distance from the antenna to the IID and because of the congestion of equipment in the pump room. This congestion can block or interrupt the pathway for the radio signal to travel from the IID to the control unit. The communication pathway was into the building around a corner, down a stairwell and around another corner. This resulted in the inability to validate two of the smears taken by the RCT on the north side of the room. In order to maintain or regain communication with the robot, we moved the antenna farther into the facility. We did not move the IID antenna any closer because we were limited by cable length. Figure 12 shows the scan of the sump located in the bottom right corner of the pump room shown in Figure 11.

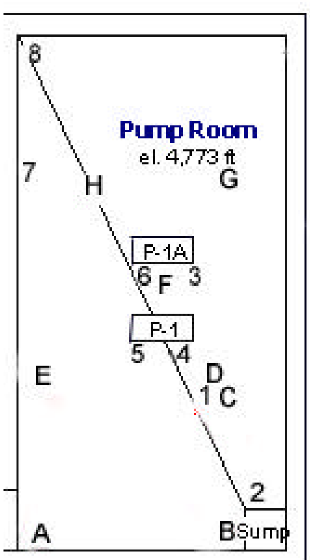


Figure 11. Characterization of the Pump Room.

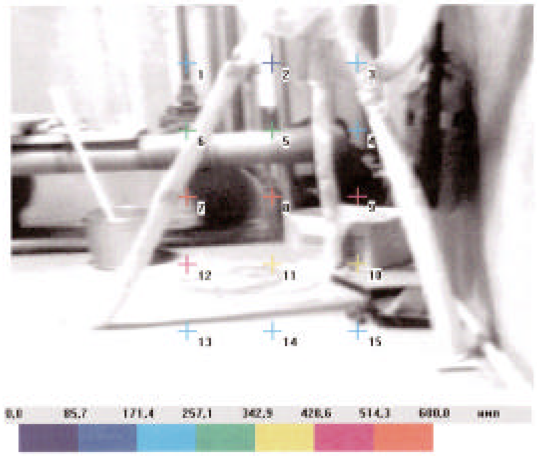


Figure 12. Radiation scan using Robotic IID in TAN-616 Pump Room

Note: Each cross hair represents a separate scanning point. The color of the cross hair indicates the radiation level that correlates to the scale below the graph. The units are in total counts in a given 10-second scan time

The following(Table 1) is a performance comparison between the IID and the baseline sampling technology. This table shows the personnel, equipment, time, PPE, capabilities and time comparison between the IID and the baseline technology.

Table I. Performance comparison between the IID and the baseline sampling technology.

Performance Factor	Baseline Characterization	IID Technology
Personnel/equipment/ time required to sample	Personnel: • 2 RCTs • 4 samplers • 1 video • 1 safety • 1 field team lead Equipment: • Ludlum 2A detector • 1 field logbook • Counting meter for the smears • Smears • Physical sampling equipment Time: • 30 hours	Personnel: • 1 operator of IID • 1 operator of the robot • 1 camera operator • 2 RCTs • 2 labors Equipment: • 1 Robot • 1 IID • 1 field logbook Time: • 18 hours
Time required to generate report	Personnel: • 1 RCT Equipment: • 1 personal computer • 1 field logbook Time: • 5 hours	Personnel: • 1 RCT Equipment: • 1 personal computer • 1 field logbook Time: • 5 hours
Total time per technology	• 35 hours	• 23 hours
Personal protective equipment (PPE)	• Rubber gloves • Safety shoes • Clothing adequate for surveying	• Rubber gloves • Safety shoes • Clothing adequate for surveying
Superior capabilities	• Technology is well known and accepted for the performance of free-release surveys	• IID was considered much easier to operate • This innovative technology has a larger widow of view • It is much faster and more efficient in collecting data • It can provide near real-time data • The final report includes a visual display of the type of contamination found.

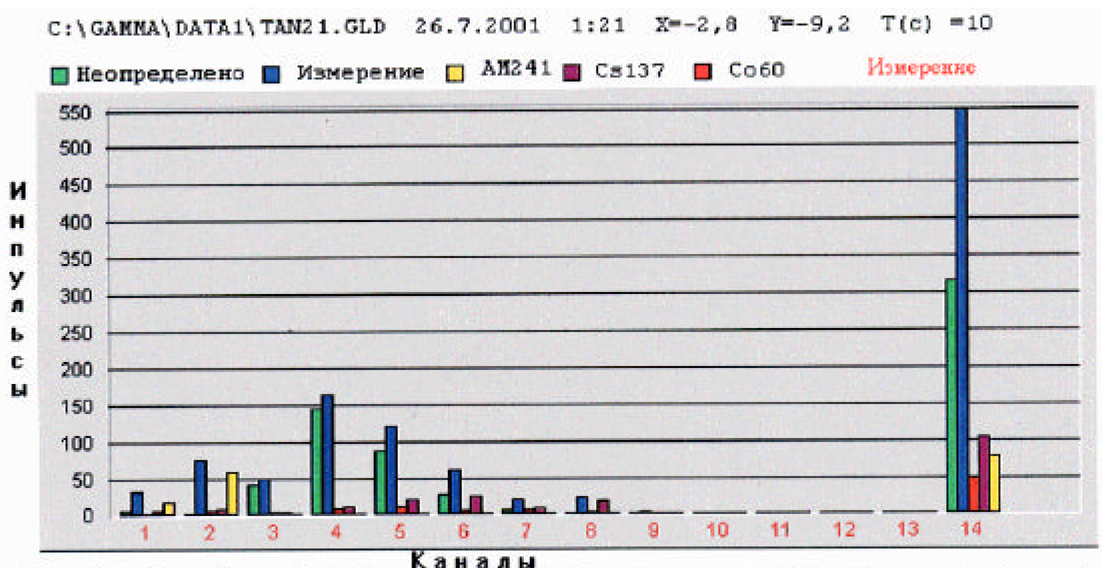
The following (Table 2) shows the IID identified all isotopes in the Pump Room when compared to the baseline sampling activity. This table can be used with figure 11 to identify the locations where samples and scans were taken.

Table 2. Isotope Locations and Types in Pump Room.

Map Location Shown on Figure 11	IID	Baseline
1	Cs137	Cs137

2	Cs137 Co 60	Cs137 Co 60
3	Cs137 Co 60	Cs137 Co 60
4	Cs137 Co60	Cs137 Co60
5	Cs137 Co60	Cs137 Co60
6	Cs137 Co60	Co60 Cs137
7	Cs137 Co60	Co60 Cs137
8	Cs137 Co60 Am241	Cs137 Co60 Am241

During the demonstration, scans were performed, in the Control Room, Operating Pump Room and Pump Room using the IID. An example of the data from these scans are shown in Figure 13. Using the IID, the isotopes present in the Control Room, Operating Pump Room and Pump Room were identified and compared with the baseline in several locations.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Неопр	7	0	41	144	88	28	6	0	2	0	0	1	1	318
Измер	33	75	49	163	120	60	20	22	4	1	1	1	1	550
Co60	1	7	3	8	11	7	5	4	2	1	1	0	0	50
Cs137	7	9	4	11	21	25	9	18	0	0	0	0	0	104
Am241	18	59	1	0	0	0	0	0	0	0	0	0	0	78

	P(p/c)	A(кюри)
Co60	3,4595E-08	1,3195E-03
Cs137	7,1958E-08	1,1393E-02
Am241	5,3968E-08	4,3226E-04
Изотроп(р/ч)	5,0000E-03	

Figure 13. IID Printout from computer

SECTION 4
TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Competing Technologies

Baseline Technology

Prior to any work being scheduled in the TAN-616 facility, RCTs and industrial hygienists entered the facility. The objective of this entry was to identify hazards such as airborne contamination, loose contamination (collected using swipes), fixed contamination, and physical hazards (e.g., leaky pipes or obstructions). This information was used to generate a radiation work permit outlining what personal protective equipment (PPE) workers needed to wear in the facility and to determine the as-low-as-reasonably-achievable (ALARA) doses to be expected by workers in the facility. Also, this information was used to determine worker stay times in the various rooms.

The next entry into TAN-616 was to obtain video footage and still photos. Workers and planners used this footage to plan and prepare work packages to complete specific tasks and be aware of hazards. The final baseline entry was completed by sample technicians to collect samples of concrete, debris, paint, sludge, and swipes to determine radioactive isotopes and other contamination needing removal as part of D&D activities.

The baseline technology for this demonstration required RCTs and sample technicians to enter the radiological areas and collect samples of material containing particles of radioactive contamination. The material was then taken to a laboratory and analyzed for isotopic content. The baseline method for identifying isotopes is very labor intensive and in many cases exposes workers to radiation fields for extended periods of time. The baseline technology also requires a process for disposal of the radioactive samples after the analysis is complete. This can be another cost added to the overall baseline isotopic identification process.

Other Competing Technologies

The Berkeley Nucleonics Surveillance and Measurement System (SAMS) Model 935 (see Figure 14) uses a thallium-activated sodium iodide (Th)NaI detector to provide the isotopic identification capability in a hand-held survey instrument. The Model 935's time slicing, data compression technique results in short acquisition times and accurate isotopic identification capabilities. Quadratic compression conversion is a data-compression technique used to enhance the algorithm, allowing operators to identify multiple isotopes in 1-second intervals. The Model 935 can detect up to 70 nuclides using an internal library of nuclides, which is expandable to 95 nuclides and has an optional neutron detector. The basic Model 935 comes with an internal 1.5 by 2-in. (Th)NaI crystal. Two other sizes (2 x 2-in. and 3 x 3-in.) are also available.

Figure 14. SAMS Model 935.

Technology Applicability

The IID is very adaptable to remote applications such as the remote demonstration at the INEEL where hard to access areas can be characterized. The IID was relatively simple to integrate onto the INEEL robot and required few modifications, as only a baseplate was required for mounting.

The IID technology is fully developed; however, upgrades and modifications are currently being made. Its outstanding performance and unique capabilities over the baseline technologies make it a prime candidate for deployment throughout the DOE complex as well as at commercial nuclear sites. The INEEL has deployed this type of technology on a variety of projects; however, the competing technologies do not provide remote capabilities. Competing technologies do not provide the autonomous operation that proved to be very valuable in areas congested with material and debris on the floor. The IID also provides a wider scanning angle and larger detection range than other competing technologies.

Patents/Commercialization/Sponsor

The IID is available from:

Research and Development Institute of Construction Technology (NIKIMT)
Altufyevskoye, Shossee 43
Moscow, Russia 127410
Phone: (7-812) 489-9095

Contact: Dr. Nikolai Sidorkin

SECTION 5
COST

Introduction

This section compares the cost of the innovative and the baseline technologies for first response or highly contaminated areas. Basis of all costs is the demonstration survey of a control room, an operating pump room, and a pump room containing scattered objects and equipment. The innovative technology cost is approximately 87 percent of the baseline technology's cost for a first response survey. However, in terms of unit cost per sample (baseline) and the unit cost per scan (innovative technology) the cost difference is more significant. Nineteen (19) samples were tested using baseline technology and 20 scans were performed with the innovative technology. Scanning unit cost of the innovative technology is approximately 82 percent of the sampling unit cost of the baseline technology.

Methodology

This analysis for first response or highly contaminated areas is based on Government ownership of the innovative technology equipment and the baseline equipment. Baseline technology is primarily hand tools and hand held equipment. The innovative system includes the IID equipment mounted on a robotic platform. Government ownership of the equipment is used in this analysis because it provides the most accurate cost comparison for the baseline technology to the innovative technology. Hourly equipment usage rates were computed for the innovative technology and the necessary robotic transporting equipment. Each rate includes ownership costs and operating costs for an equipment service life of 5,000 hours.

In this demonstration, Russian personnel provided IID operation assistance for the innovative technology. This cost analysis assumes that both the innovative technology and the baseline technology use site labor. The crews used in the cost analysis are based on the test engineer's judgment. Crews include a hygienist at one quarter time and a supervisor present one day because they are not required to be present for the duration of survey work. The assumption is that both would perform duties at multiple jobs. The cost analysis is based on current burdened labor rates for the labor categories conducting this work.

In some cases, the activity duration observed during the demonstration does not represent the cost of typical work because of the artificial affects imposed on the work. These artificial affects are the result of the need to collect data, first time use of the equipment, and other effects associated with the demonstration. In these cases, the observed duration is adjusted before using them in the cost analysis. An example is the presence of additional management INNEL staff and others present during the demonstration of the Russian equipment. These types of manpower and events were not included in the cost analysis. No other potential discrepancies between the demonstration and typical work were observed.

Additional details of the basis of the cost analysis for the surveys are described in Appendix B.

Cost Analysis

Costs to Procure Innovative Equipment

The innovative technology would be acquired by a direct purchase. The cost associated with this acquisition is indicated in Table 3.

Table 3. Innovative Technology Costs

Acquisition Option	Item Description	Cost
Purchase	Isotopic Identification Device (IID)	$30,000
Purchase	Robotic Platform	$20,000

Unit Costs and Fixed Costs

Table 4 shows the unit costs and fixed costs for both innovative and baseline technologies. The fixed costs are the sum of the line items shown in Table B-2 and B-3 that do not vary directly with the size of the job. The unit costs are the sum of the line items shown in Table B-2 and B-3 that do vary with the size of the job. The sum of unit costs is divided by the number of samples (19 ea. - baseline) and the number of scans (20ea - innovative technology) to arrive at a unit cost per sample/scan.

Table 4. Summary of Unit Costs and Fixed Costs

COST ELEMENT	INNOVATIVE COST	BASELINE COST
Fixed Costs	$ 1,966	$ 1,875
Variable Costs	$ 19,877	$ 23,397
Number of Units	20 ea.	19 ea.
Unit Costs	$ 994 per scan	$1,231 per sample
TOTAL COSTS	$ 21,843	$ 25,272

Note: The fixed costs are the sum total of individual tasks that are fixed and these line items are indicated in the right hand column of Table B-2 and Table B-3. The unit costs are the sum total of all costs that vary with the quantity of work and the sum total is divided by the number of scans for the innovative technology and by the number of samples for the baseline technology. Those line items that make up the unit cost are indicated in the right hand column of Table B-2 and Table B-3.

Break-Even Point

The innovative technology is more cost effective than the baseline technology based on the calculated unit cost of samples and scans. Consequently, there is no break-even point for a comparison between the innovative technology and the baseline technology. Figure 15 illustrates the cost difference as the number of samples/scans increases. Fixed costs are included.

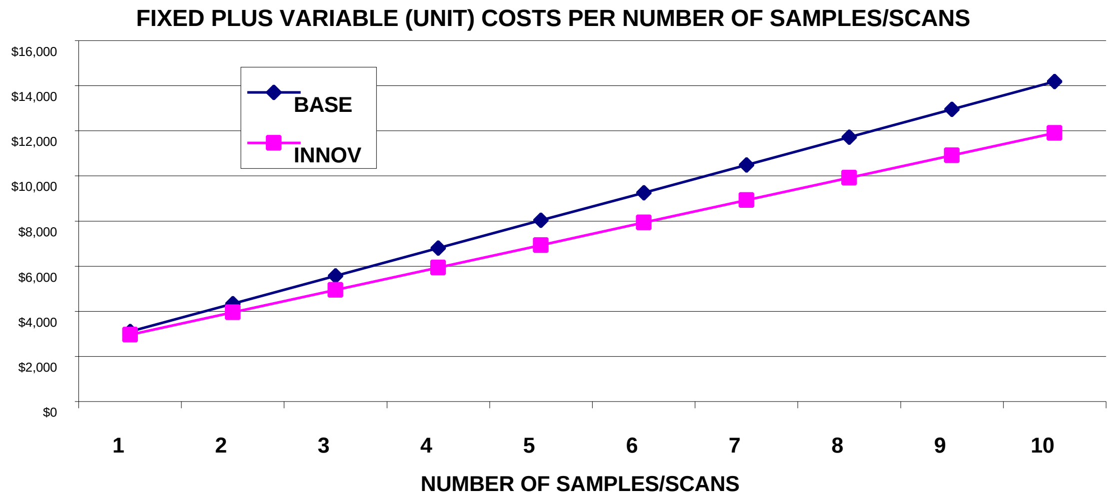


Figure 15. Illustration of Unit Costs plus Fixed Costs per samples/scans

Payback Analyses

This analysis assumes the innovative technology is purchased and owned by the Government. Cost of equipment is recouped by an hourly equipment rate. The baseline technology also utilizes Government owned equipment. Variable unit cost savings of the innovative technology over the baseline technology is approximately $237 per sample ($1,231 minus $994, assuming equivalent survey results for 1 sample and 1 scan). At this savings, approximately 211 scans would make up for the purchase price of the innovative technology equipment ($50,000 / $237 per sample = 211 scans).

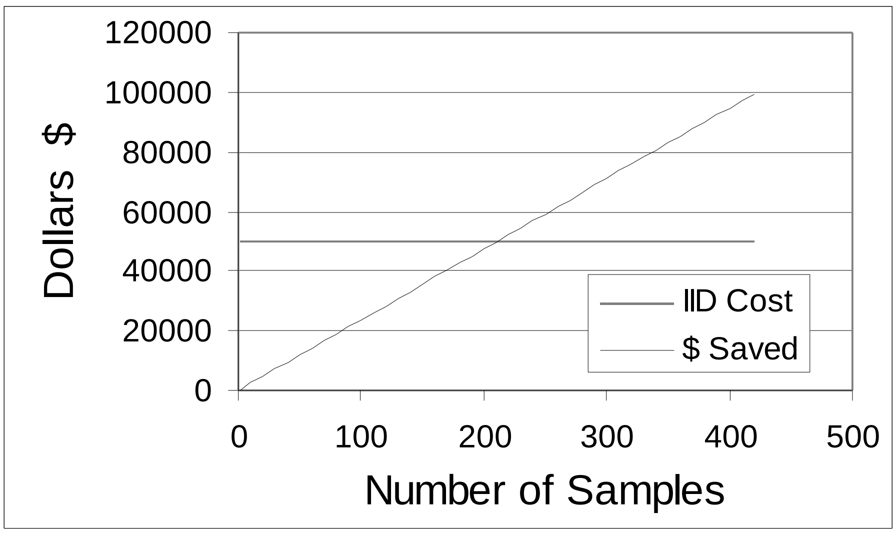


Figure 16. Payback Analysis.

Safety and Exposure Concerns

Radiological exposure during the demonstration was 82 mR for the baseline technology and only 7 mR during the demonstration of the IID. Using the innovative technology resulted in a reduction in radiation exposure of 75 mR. While the values themselves are not significant, the fact the use of the IID resulted in a factor of more than 10 times reduction in radiation dose received is significant. While it is difficult to affix a dollar value to reduction in dose received, the DOE has established a saving resulting from dose reduction of $6,800 per man Rem. On jobs where the radiation exposure is much higher, a reduction in exposure of 10 times would be significant.

Observed Costs for Demonstration

Figure 16 summarizes the observed costs for the innovative and baseline technology based on 20 scans and 19 samples respectively. Figure 17 is the comparison of overall scan and sample unit costs. Contents of the demonstration room include wall mounted electrical services, equipment and miscellaneous debris. The details of these costs are shown in Appendix B and includes Tables B-2 and B-3 which can be used to compute site-specific cost by adjusting for number of samples or scans, different labor rates, crew makeup, etc.

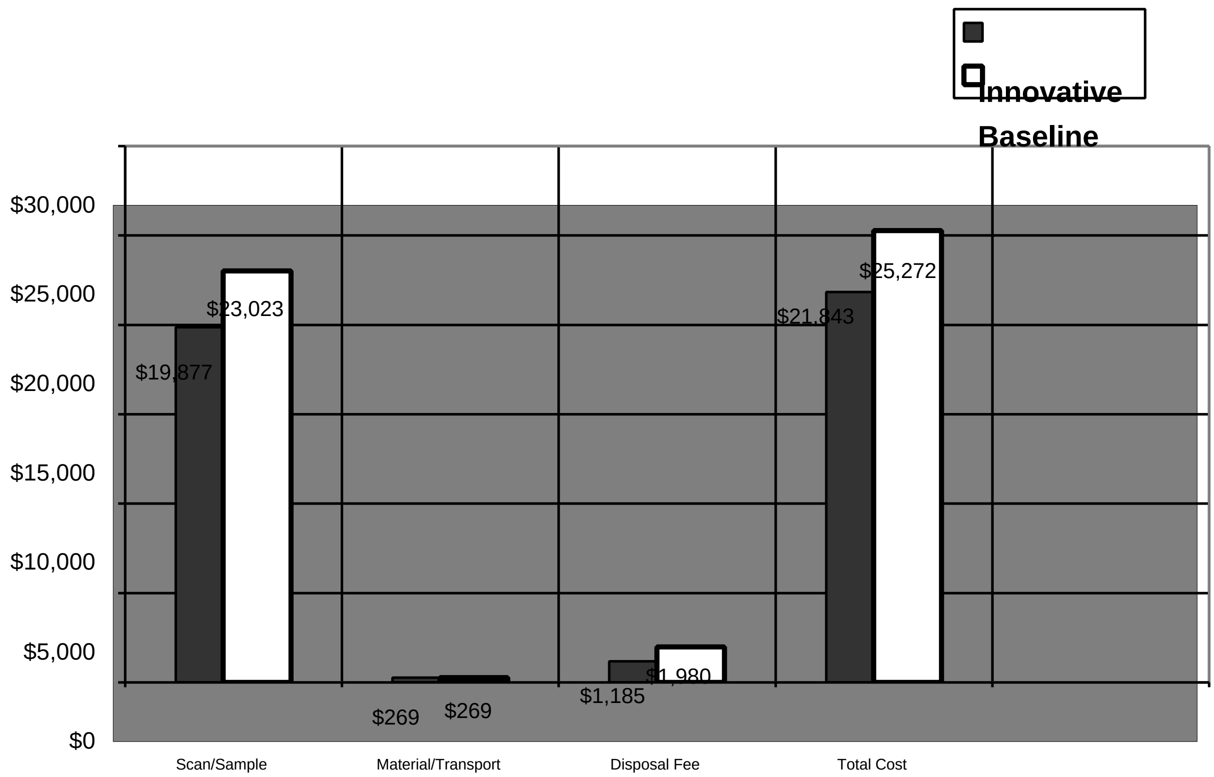


Figure 17. Summary of technology Unit costs

Cost Conclusions

The innovative technology costs for Investigation and Monitoring/Sample Collection (work breakdown structure # 4.07.14) is primarily variable costs associated with time, labor, and equipment to conduct a room survey for first response. The cost is also dependent upon the specifics of each individual project. Examples of individual variables may include requirements for specific isotope detection, the field of view desired, the level of detection, and the geometry of each scan.

Innovative costs are based on completing 20 scans and the baseline collected and tested 19 samples. As the room size increases, the economies of the innovative technology would be significant. This is illustrated by the demonstration. Overall demonstration time for both baseline and innovative were approximately equal, 36 and 39 hours respectively. However, during one day of baseline sampling the number of sampling technicians was doubled. Consequently, the comparison of the innovative technology to the baseline technology appears to be sensitive to the job size.

The innovative technology and baseline technology costs for Materials Handling/Transportation (Environmental Cost Element Structure work breakdown structure #4.13) and Disposal Facility (Environmental Cost Element Structure work breakdown structure #4.32) may vary in cost from one DOE site to the next. But, the variation in these costs is not anticipated to affect the cost comparison between the innovative technology and the baseline technology.

The innovative technology cost savings over the baseline technology will vary depending on the site-specific requirements of the work. Assuming the survey needs are satisfied by 1 sample test equaling 1 scan result, then for most real work situations, the innovative technology should cost approximately 85 percent of the baseline cost for general area surveys.

SECTION 6

OCCUPATIONAL SAFETY AND HEALTH

Prior to arrival at the INEEL, the Russian Research and Development Institute of Construction Technology (NIKIMT) identified all hazards associated with the operation of the IID technology. The primary hazard associated with this technology is the weight of the remote head while lifting and mounting it on the robotic platform. The weight of the head is in excess of 60 pounds and requires two people to safely lift and place it on the robot.

During operation of the IID, it was recommended by NIKIMT personnel to avoid lingering in front of the antennas, as potential exposure to the transmitter signal should be avoided whenever possible.

All NIKIMT personnel were required to attend a training course on the general health and safety procedures specific to the INEEL. Included in this training was facility access and general employee radiological training. This training was required to raise the awareness of hazards associated with radiological and industrial work specific to the demonstration and deployment of the IID at INEEL facilities.

Pre-job and post-job briefings were conducted on a daily basis during the execution of this demonstration. Hazards associated with this demonstration area were explained during the pre-briefings, and the appropriate PPE was also discussed. During the pre-job briefings, the job safety analysis documentation was reviewed, and all hazards and potential hazards were reviewed and mitigated where possible. The post-job briefings reviewed any problems or potential hazards, observations, and recommendations for follow-on deployments.

Two technicians and one RCT entered the facility during the demonstration to assist the movement of the IID up and down the stairs and to check air quality prior to entering the facility. The individuals who entered maintained as much distance between themselves and the highest contaminated areas as possible. In contrast, the baseline samplers were required to come in direct contact with the contaminated material in order to collect representative samples.

An Ultra Lift Motorized Handcart was used to transport the IID down the stairs to the lower level of TAN-616. The Ultra Lift traversed the stairs without incident and eliminated the need to knock out walls or prepare extensive safety reviews and procedures to manually move the robot to the basement. The operation was a simple task for two people, one to operate the handcart controls and one to stabilize the load. This operation typically would have taken four people with special safety precautions to prevent loss of control of the load and would expose workers to possible injury from lifting and maneuvering in awkward positions. D&D operations personnel were excited about the new handcart and now make it available for use in every facility.

SECTION 7
REGULATORY AND POLICY ISSUES

Regulatory Considerations

For this demonstration, a test plan and the technical procedure covered the use of the IID under the INEEL LSDDP.

Because the IID operates at frequencies of 780 MHz and 3.4 GHz, it was necessary to obtain special approval for operation in the United States. This approval was granted under an "Authorization for Experimental Authority" at the INEEL. This approval requested authority under the National Telecommunications Information Administration Manual 7.11 to conduct a short-term evaluation of a GLD and IID at TAN, the Power Burst Facility (PBF), and NBA.

The use of this device was approved by the DOE-ID frequency coordinator prior to the demonstration.

Safety, Risks, Benefits, and Community Reaction

The safety issues associated with the use of the IID are primarily moving the scanning head for each scan. These risks are mitigated by the use of a robot to move the IID. In areas that the robot cannot access, other measures must be taken such as using a handcart or "Ultra Lift" for this positioning activity. The deployment team used an Ultra Lift to transport the robot down the stairs at TAN-616. Employees were not allowed to lift more than 50 pounds or one-third of their body weight. Back-safety awareness training was required for this phase of the demonstration.

During operation of the IID it was recommended by NIKIMT personnel to avoid lingering in front of the antennas, as potential exposure to the transmitter signal should be avoided whenever possible.

All radiological areas were posted, and the employees were trained as a Radiological Worker II. A trained radiological worker was required to escort all employees not trained.

The IID:

- Eliminates the need for manual sample retrieval
- Reduces radiological exposure to workers
- Reduces labor costs (fewer people are needed to obtain data)
- Eliminates waste (due to sample disposal requirements and PPE)
- Reduces time required for data analysis
- Provides detailed scan of radiological areas in real time.

The IID was very well received be the community and provided valuable information as to the isotopic content in TAN-616.

SECTION 8

LESSONS LEARNED

Implementation Considerations

The IID technology is mature and provided meaningful, near real-time isotopic data during the INEEL demonstration. Operating the IID and the Russian-developed software requires user training and familiarity. Due to the language and interpretation requirements necessary to operate the IID, the Russians were the only qualified operators of the IID system during the INEEL demonstration. An operator manual needs to be developed that provides conversions, operator instructions, and training before it would be possible for an end user to operate the IID. According to D&D operations, this technology is much faster and easier to use than the baseline hand-sampling methodology typically used for characterization. The system generated high-quality data, with visual presentation of the results. Items that should be considered before implementing the IID include the following:

- Warranty and availability of parts and spare parts.
- Special permission is required to operate the IID at the current frequencies.
- Background radiation levels should be determined prior to entering the survey area. Generally, background measurements are collected from the adjacent area(s) considered clean.
- During this demonstration, there were complications with calibration due to software errors.
- Although it is expected to be an uncommon occurrence, a component failure in the pan motion resulted in a delay of several hours.
- Operator training/certification.
- Calibration/certification of the IID to operate in the U.S.

Technology Limitations and Needs for Future Development

In some cases, it may not be possible to compare the detection limits of the baseline technology (sampling/lab analysis) and the IID directly, as the two may (in some cases) not be directly related. The baseline provides measurements for surface gamma readings in units of counts per minute. The detection limits for the baseline technology are limited to surface areas where the samples are retrieved.

The IID obtained readings in some areas that appeared to be internal to piping and vessels. These areas were inaccessible by the baseline sampling methods and could not be compared with the IID. This can be an advantage if internal isotopic identification is of concern; however, discriminating between internal and external readings can be difficult, especially if some level of contamination is on both areas of a pipe or vessel. The IID cannot provide quantitative results at levels below those observed using the baseline technology. The detection limits of the IID are also variable and depend on count time, isotope of concern, and background levels.

The IID would be more user friendly if the software was upgraded to English and provided the user with U.S. standard units. The IID would also benefit by being deployed separately from the GLD. Currently, it can only be operated in conjunction with the GLD, thus requiring a larger computer system and data processing program. Also, deployment time could be shortened, which would reduce the cost of an overall characterization process if isotopic identification were the only data points needed.

APPENDIX A
REFERENCES

Yancey, Neal, 2001, "Robotic Gamma Locator Device (GLD)," *Innovative Technology Summary Report*, U.S. Department of Energy, OST/TMS ID 2991.

APPENDIX B
COST COMPARISON DETAILS

Basis of Estimated Cost

The activity titles shown in this cost analysis come from observation of the work. In the estimate, the activities are grouped under higher-level work titles per the work breakdown structure (WBS) shown in the ***Environmental Cost Element Structure*** (ECES).

The costs shown in this analysis are computed from observed duration and hourly rates for the crew and equipment. The following assumptions were used in computing the hourly rates:

- This cost analysis assumes the Government owns the innovative technology equipment.
- The equipment hourly rates for equipment that is owned by the Government is based on general guidance contained in Office of Management and Budget (OMB) Circular No. A-94, ***Cost Effectiveness Analysis***. This involves amortizing the purchase price of the equipment over the anticipated service life of the equipment. The rates also include annual maintenance costs. A service life of five thousand hours is assumed for the innovative technology and robotic equipment.
- Some of the equipment used in the course of the demonstration is commonly included in the site motor pool, such as vehicles. The equipment rates for these types of equipment are based on standard fleet rates for INEEL.
- Labor rates used in this estimate are burdened rates including salary, fringes, overheads, and other facility markups.
- The basic crew used for the baseline cost analysis is based on the test engineer's judgment including two radiological control technicians, two radiological engineers, one industrial hygienist, two sample technicians, and one job supervisor.
- The basic crew during IID scanning included a hygienist at one-quarter time, two radiation control technicians, two test engineers, one robotics engineer, and one robotics technician.

The analysis does not include costs for oversight engineering, quality assurance, administrative costs for the demonstration, or work plan preparation costs.

Activity Descriptions

The scope, computation of production rates, and assumptions (if any) for each work activity is described in this section.

INVESTIGATIONS AND MONITORING/SAMPLE COLLECTION, CONTAMINATED BUILDING/STRUCTURES SAMPLES (WBS 4.07.14)

ALARA REVIEW: This activity includes the time required for the Radiation Engineer/s to complete a review of the current conditions at the site and make a determination for stay times and acceptable dose levels to be received by the workers.

PICKUP & CHECK (CALIBRATE) EQUIPMENT: This activity includes picking up the GLD and robot from a storage facility in the case of the innovative technology and transport of the baseline technology equipment from a storage facility to the work area. Time required for this activity for both the baseline and innovative technology is based on the judgment of the test engineer.

PROJECT MANAGER: This line item accounts for the time a project manager will input into the project in planning and preparing to complete the task.

INITIAL SURVEYS: The following activities are required to complete the initial surveys which are made by radiation control technicians prior to the startup of the task.

TRAVEL TO WORK AREA: This activity is the crews travel time to the work area based on the duration observed in the demonstration.

PRE-JOB BRIEFING: The duration for the pre-job safety meeting is based upon the observed time for the demonstration. Activities included the worksite check-in and a review of the safety plan. The labor costs for this activity are based upon an assumed crew (rather than the actual demonstration participants, and all subsequent activities are based on the assumed crew).

DON PPE AND ENTER: This activity includes the labor and material cost for donning the articles of clothing listed in Table B-1 and entry of the radiological control zone. The estimates assume that the workers leave the radiological control zone for lunch breaks and this requires an additional doffing and donning of PPE.

DOFF PPE: This activity applies to both the innovative technology and the baseline technology and includes the labor costs for doffing PPE and is based on the duration observed in the demonstration.

TRAVEL BACK: This activity is the crews travel time from the work area based on the duration observed during the demonstration.

SAMPLING ACTIVITY: This section applies to both the baseline and innovative activity. However, some items only relate to the baseline while others relate only to the innovative technology, for example bagging the GLD obviously only applies during the innovative activities.

TRAVEL TO WORK AREA: This activity is the crews travel time to the work area based on the duration observed in the demonstration.

PRE-JOB BRIEFING: The duration for the pre-job safety meeting is based upon the observed time for the demonstration. Activities included the worksite check-in and a review of the safety plan. The labor costs for this activity are based upon an assumed crew (rather than the actual demonstration participants, and all subsequent activities are based on the assumed crew).

UNLOAD AND SETUP: The time required for daily checks and calibration is based on duration observed in the demonstration.

DON PPE AND ENTER: This activity includes the labor and material cost for donning the articles of clothing listed in Table B-1 and entry of the radiological control zone. The estimates assume that the workers leave the radiological control zone for lunch breaks and this requires an additional doffing and donning of PPE.

Table B-1 Cost for PPE (per man/day)

Equipment	Cost Each	Number of Times Used Before Discarded	Cost Each Time Used ($)	No. Per Use	Cost Per Use ($)
Boot Covers (pair)	$1.02	1	$1.02	2	$2.04
Rubber boots with liner pair	$64.98	50	$1.30	2	$2.60
Facepiece	$18.98	30	$0.63	1	$0.63
Filter Cartridge	$7.43	1	$7.43	1	$7.43
Cleaning Wipes/ Consumables	$2.00	1	$2.00	1	$2.00
Glove liners pr. (cotton inner)	$0.40	1	$0.40	2	$0.80
Rubber Gloves pair (outer)	$1.51	1	$1.51	2	$3.02
Coveralls (white Tyvek)	$4.66	1	$4.66	2	$9.32
Hood	$0.85	1	$0.85	2	$1.70
Hard Hat	$11.45	30	$0.38	1	$0.38
Face Shield	$27.74	20	$1.39	1	$1.39
Safety Glasses	$4.80	30	$0.16	1	$0.16
TOTAL COST/USE/PERSON					**$31.47**

SAMPLING: This activity applies only to the baseline. Sampling is the physical removal of a sample for analysis and testing. The time required calculating the cost of typical work for this activity is based on the duration observed in the demonstration.

BAG IID: This activity applies only to the innovative technology. Work is preparatory to entering contaminated space.

ASSEMBLE ROBOT AND IID SYSTEM: This activity applies only to the innovative technology. Tasks include placing the IID on the robot and testing the robotic system. The time required for this activity is based on observations during the demonstration.

SCANNING: This activity applies only to the innovative technology. Scanning is performed remotely controlled by a robotics technician with over-site by a robotics engineer. Scanning data collection is performed by the test engineers. Time required for the tasks under this activity is based on the duration observed during the demonstration.

EXIT AND UN-BAG EQUIPMENT: This activity applies only to the innovative technology. Tasks include removal of protective covering and disassembling IID and robot equipment. This effort is assumed to reduce or eliminate decontamination of the equipment. The time required for this activity is based on observations during the demonstration.

DOFF PPE: This activity applies to both the innovative technology and the baseline technology and includes the labor costs for doffing PPE and is based on the duration observed in the demonstration.

TRAVEL BACK: This activity is the crews travel time from the work area based on the duration observed during the demonstration.

TRAVEL TO WORK AREA: This activity is the crews travel time to the work area based on the duration observed in the demonstration.

PRE-JOB BRIEFING: The duration for the pre-job safety meeting is based upon the observed time for the demonstration. Activities included the worksite check-in and a review of the safety plan. The labor costs for this activity are based upon an assumed crew (rather than the actual demonstration participants, and all subsequent activities are based on the assumed crew).

UNLOAD AND SETUP: The time required for daily checks and calibration is based on duration observed in the demonstration.

DON PPE AND ENTER: This activity includes the labor and material cost for donning the articles of clothing listed in Table B-1 and entry of the radiological control zone.   The estimates assume that the workers leave the radiological control zone for lunch breaks and this requires an additional doffing and donning of PPE.

VIDEO: This activity applies only to the baseline. Sampling is the physical removal of a sample for analysis and testing. The time required calculating the cost of typical work for this activity is based on the duration observed in the demonstration.

EXIT AND UN-BAG EQUIPMENT: This activity applies only to the innovative technology. Tasks include removal of protective covering and disassembling IID and robot equipment. This effort is assumed to reduce or eliminate decontamination of the equipment. The time required for this activity is based on observations during the demonstration.

DOFF PPE: This activity applies to both the innovative technology and the baseline technology and includes the labor costs for doffing PPE and is based on the duration observed in the demonstration.

TRAVEL BACK: This activity is the crews travel time from the work area based on the duration observed during the demonstration.

OTHER ACTIVITIES: This activity is used to describe the time during the demonstration of the innovative technology where data was being interpreted, adjustments were being made, calibrations were being checked etc. All of the personnel remained onsite, but were waiting for sampling activities to resume.

RETURN EQUIPMENT TO STORAGE: This activity applies to both the innovative technology and the baseline technology and includes transporting the equipment back to the respective storage facilities and unloading. The activity duration is based on the duration observed in the demonstration and the test engineer's judgment.

FINAL POST JOB BRIEFING: Following the completion of the task, post job briefing is held to review the outcome of the sampling activity, discuss the results, and evaluate the success of the project.

DISPOSAL FACILITY, DISPOSAL FEES AND TAXES (WBS 4.13)

DISPOSAL: The laboratory analysis fee includes the cost of returning the sample remains and that effort is not shown as a separate cost in this analysis. This cost is for disposal of PPE used in the course of the work and is based on the assumption that each worker generates 0.66 cf of waste per day. The baseline technology requires a number of individuals to don PPE for each sampling activity. This will include RCT's and sampling technicians. For the innovative technology it is estimated that two workers will don PPE for each scanning activity. Disposal costs at INEEL are assumed to be $150 per cubic foot of waste based on historic costs observed at INEEL for operation of the disposal cell. These costs do not include costs for transportation, packaging the waste, closure of the disposal facility, or long term maintenance and surveillance.

MATERIALS HANDLING/TRANSPORTATION (WBS 4.32)

SOLID WASTE TRANSPORT: This activity applies to both the innovative technology and the baseline technology and includes loading the waste onto a truck, transport to the disposal area, and unloading. The activity estimate is 1 hour to load, 1 hour to transport, and 1 hour to unload for each trip based on previous experience at INEEL.

Cost Estimate Details

The cost analysis details are summarized in Tables B-2 and B-3. The tables break out each member of the crew, each labor rate, each piece of equipment used, each equipment rate, each activity duration and all production rates so that site specific differences in these items can be identified and a site specific cost estimate may be developed.

Table B-2. Baseline Technology Cost Summary

Unit/ Fixed Cost	**Work Breakdown Structure**	**Unit**	**Unit Cost $/Unit**	**Quantity**	**Total Cost**	**Computation of Unit Cost**							**Comments**
						Prod Rate (unit/hr)	Duration (hr)	Labor Item	$/ Activity	Equipment Items	$/hr	$/ Activity	

	Facility Deactivation, Decommissioning, & Dismantlement											**Total Cost =**	**$ 25,272**
	INVESTIGATIONS AND MONITORING/SAMPLE COLLECTION, CONTAMINATED BUILDING/STRUCTURES SAMPLES (WBS 4.07.14)											Subtotal =	$ 23,023
Fixed	ALARA Review	Hr	86.48	4	346								
Fixed	Init. Pickup/Check Equip.	Hr	183.31	1	183		1	RCT,2ST	162.12	PU,ST	21.19		
Fixed	Project Manager	Hr	100.00	8	800								
Unit	Initial Surveys								**Initial Survey**				
						73.65	10	TL	736	PU	9.02	90	
						66.48	10	IH	664	ST	1.57	16	
						52.12	10	2-RCT	1042	PPE	12.60	126	
						52.12	10	2-TE	1042				
		Hr	371.80	10	**3,718**				**3,486**			**232**	
Unit	Sampling								**1st Sampling Activity**				
						66.48	16.25	IH	1080	2-PU	18.04	293	
						52.12	16.25	2-RCT	1693	2-ST	3.14	51	
						86.48	16.25	2-RE	2810	PPE	11.57	188	
						55.00	16.25	2-ST	1787				
		Hr	790.45	10	**7,905**				**7372**			**532**	
Unit	Sampling								**2nd Sampling Activity**				
						52.12	6	2-RCT	625	2-ST	6.28	37	
						86.48	6	2-RE	1037	PPE	21.00	126	
						55.00	6	2-ST	1320	PU	18.05	108	
		Hr	542.50	6	**3,255**				**2,983**			**272**	
Unit	Sample Test	Ea	330.00	19	**6,270**								
Fixed	Return Equip. to Storage	Hr	183.31	.5	92		.5	RCT,2ST	162.12	PU,ST	21.19		
Fixed	Final Post Job Briefing	Hr	453.68	1	454		1	IH,2RCT,2RE,2ST	453.68				
	MATERIALS HANDLING/TRANSPORTATION (WBS 4.32)											Subtotal =	$ 269
Unit	Solid Waste Transport	hr	89.65	3	$ 269		3	TD, LB, 1/4 EO	57.96	FB, 1/4FL	31.70		
	DISPOSAL FACILITY, DISPOSAL FEES AND TAXES (WBS 4.13)											Subtotal =	$ 1,980
Unit	Disposal Fees & Taxes	Cf	150.00	13.20	$ 1,980								
				Subtotal Unit Costs	23,397								
				SAMPLES	19								
				UNIT COST PER SAMPLE	**1,231**								

Labor and Equipment Rates used to Compute Unit Cost

Crew Item	Rate $/hr	Abbre-viation	Crew Item	Rate $/hr	Abbrev-iation	Equipment Item	Rate $/hr	Abbrev-iation	Equipment Item	Rate $/hr	Abbrev-iation
Field Team Lead	73.65	FTL	Project Manager	100.00	PM						
Industrial Hygienist	66.48	IH	Sample Technician	55.00	ST	Pickup	9.02	P			
Radiation Ctrl Technician	52.12	RCT				Flatbed Truck	25.48	FB			
Test Engineer	52.12	TE	Equipment Operator	44.66	EO	Small Tools	1.57	ST			
Radiological Engineer	86.48	RE	Truck Driver	46.79	TD	Fork Lift	6.62	FL			

Notes:

1. Unit cost = Total Cost / Qty
2. Abbreviations for units: ea = each, cf = cubic feet
3. Other abbreviations: PPE = personal protective equipment, Decon = Decontaminate, Loc = Location, Equip = equipment, Tech = Technician, Prod = Production.

Table B-3. Innovative Technology Cost Summary

Fixed/ Unit Costs	Work Breakdown Structure	Unit	Unit Cost $/Unit	Quantity	Total Cost	Computation of Unit Cost							Comments
						Prod Rate	Duration (hr)	Labor Item	$/hr	Equipment Items	$/hr	Other $	
	Facility Deactivation, Deconmmissioning, & Dismantlement												**TOTAL = $ 22,073**
	INVESTIGATIONS AND MONITORING/SAMPLE COLLECTION, CONTAMINATED BUILDING/STRUCTURES SAMPLES (WBS 4.07.14)												Subtotal = **$ 20,619**
Fixed	ALARA Review	Hr	86.48	4	$ 346								
Fixed	Init. Pickup/Check Equip.	Hr	183.31	1	$ 183		1	RCT,2ST	162.12	IID,ROB,PU	21.19		
Fixed	Project Manager	Hr	100.00	8	$ 800								
Unit	Scanning Activity					**Scanning Activity**							
						73.65	21	TL	1546	PPE	13.60	286	
						66.48	21	1/4IH	349	IID	14.26	299	
						52.12	21	2RCT	2189	RP	10.62	223	
						52.12	21	2TE	2189	2-PU	2.93	61	This equip. on Standby
						84.09	21	ROE	1766	ST	1.57	33	
						55.00	21	RT	1155				
		Hr	480.82	21	**$ 10,098**				**9,195**			**903**	
Unit	Other Activities					**Other Activities**							
						73.65	18	TL	1326				
						66.48	18	1/4IH	299	IID	3.71	67	This equip. on Standby
						52.12	18	2RCT	1876	RP	2.47	44	This equip. on Standby
						52.12	18	2TE	1876	2-PU	18.05	325	
						84.09	18	RE	1514	ST	.47	8	This equip. on Standby
						55.00	18	RT	990				
		Hr	465.01	18	**$ 8,326**				**7,881**			**444**	
Fixed	Return Equip. to Storage	Hr	183.31	1	$ 183		½	RCT,2ST	162.12	IID,ROB,PU	21.19		
Fixed	Final Post Job Briefing	Hr	453.68	1	$ 454		1	IH,2RCT,2RE,2ST	453.68				
	MATERIALS HANDLING/TRANSPORTATION (WBS 4.32)										Subtotal =		**$ 269**
Unit	Solid Waste Transport	Hr	89.65	3	$ 269		3	TD, 1/4 EO	57.96	FB, 1/4FL	31.70		
	DISPOSAL FACILITY, DISPOSAL FEES AND TAXES (WBS 4.13)										Subtotal =		**$ 1,185**
Unit	Disposal Fees & Taxes	cf	150.00	7.9	$ 1,185								

Subtotal Unit Costs	19,877
SAMPLES	20
UNIT COST PER SAMPLE	**$ 994**

Labor and Equipment Rates used to Compute Unit Cost											
Crew Item	**Rate $/hr**	**Abbre-viation**	**Crew Item**	**Rate $/hr**	**Abbrev-iation**	**Equipment Item**	**Rate $/hr**	**Abbrev-iation**	**Equipment Item**	**Rate $/hr**	**Abbrev-iation**
Field Team Lead	73.65	FTL	Project Manager	100.00	PM	Isotopic Identification Device	14.26	IID			
Industrial Hygienist	66.48	IH	Sample Technician	55.00	ST	Pickup	9.02	PU			
Radiation Ctrl Technician	52.12	RCT				Flatbed Truck	25.48	FB			
Test Engineer	52.12	TE	Equipment Operator	44.66	EO	Small Tools	1.57	ST			
Radiological Engineer	86.48	RE	Truck Driver	46.79	TD	Fork Lift	6.62	FL			
Robotic Engineer	84.09	ROE				Robotic Platform	10.62	ROB			

Notes:

4. Unit cost = Total Cost / Qty
5. Abbreviations for units: ea = each; cf = cubic feet;
6. Other abbreviations: PPE = personal protective equipment, Decon = decontaminate, Loc = Location
   Equip = equipment, Prod = Production, Tech = Technician

APPENDIX C
INEEL Robotic Platform

Figure C-1 shows the robotic platform used for demonstrating the Russian IID. ATRV-Jr™ is a small tetherless robotic vehicle that offers many of the same features and advantages of a larger robot, including four-wheel drive, differential steering, pneumatic tires, and a weather-resistant enclosure. This vehicle can be used to carry equipment and perform tasks in locations where people are banned.

Figure C-1. INEEL robotic platform.

The technical specifications of this robotic platform are given in Table C-1.

Table C-1. Technical specifications of the IID robotic platform.

Sonar	17 (6 forward, 10 side, and 2 rear facing)
CPU	Pentium II processor
Communications	Wireless 3 Mbps Ethernet
Networking	Onboard 10baseT
Batteries	2 lead acid, 672 W/hr
Run Time	3 to 6 hours terrain dependent
Motor	2 high-torque, 24-V DC servo motors
Drive	4-wheel differential
I/O Ports	Joystick, RS-232, FARnet
Turn Radius	Zero (skid steer)
Translate Speed	1 m/s (3.3 ft/s)
Rotate Speed	120 degrees per second
Payload	25 kg (55.1 lb)
Dimensions	Height – 55 cm (21.6 in.) Length – 77.5 cm (30.5 in.) Width – 64 cm (25.2 in.)
Weight	50 kg (110 lb)

APPENDIX D
ACRONYMS AND ABBREVIATIONS

ALARA	As Low As Reasonably Achievable
Am	Americium
ATRV-Jr.	All Terrain Robotic Vehicle-Junior
CFA	Central Facilities Area
Co	Cobalt
Cs	Cesium
D&D	Decontamination and Decommissioning
DC	Drect Current
DOE-HQ	Department of Energy-Headquarters
DOE	Department of Energy
GHz	Gigahertz (frequency range)
GLD	Gamma Locator Device
INEEL	Idaho National Engineering and Environmental Laboratory
IID	Isotopic Identification Device
LSDDP	Large-Scale Demonstration and Deployment Project
mR/hr	1000 Milliroentgen per Hour
MHz	Megahertz (frequency range)
NBA	North Boulevard Annex
NETL	National Energy Technology Laboratory
NIKIMT	Research and Development Institute of Construction Technology
OST	Office of Science and Technology
PC	Personal Computer
PBF	Power Burst Facility
PPE	Personal Protective Equipment
RCRA	Resource Conservation and Recovery Act
RCT	Radiological Control Technician
SBD	Spectrometric Block of Detection
SAMS	Surveillance and Measurement System
TAN	Test Area North
TMS	Technology Management System
V	Volt
WBS	Work Breakdown Structure